journal of prosthodontic research xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Prosthodontic Research

journal homepage: www.elsevier.com/locate/jpor

Original article

Five year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers — a retrospective study

Farahnaz Nejatidanesh[a], Ghazal Savabi[a], Mehrak Amjadi[b], Mahsa Abbasi[c], Omid Savabi[d,*]

[a] Dental Materials Research Center, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran
[b] School of Dentistry, Qazvin University of Medical Sciences, Qazvin, Iran
[c] School of Dentistry, Shahrekord University of Medical Sciences, Shahr-e kord, Iran
[d] Dental Research Center, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

ARTICLE INFO

Article history:
Received 19 July 2017
Received in revised form 11 May 2018
Accepted 17 May 2018
Available online xxx

Keywords:
CEREC
Computer-aided design
Dental restoration failure
Dental veneers
Survival analysis
Treatment outcome

ABSTRACT

Purpose: The aim of this clinical study was to compare the survival, modified California Dental Association (CDA) criteria, and periodontal parameters of laminate veneers made with Empress CAD and emax CAD over 60 months.
Methods: One hundred and ninety seven ceramic laminate veneers were placed in 71 patients in a private practice. The restorations were made using CEREC AC Bluecam with Empress CAD and emax CAD blocks. Modified CDA guidelines were used to evaluate clinical performance of the restorations. Gingival and plaque indices, probing pocket depth, and bleeding on probing were also recorded. Patient's satisfaction was assessed using visual analogue scale. Kaplan–Meier and Log rank test were used to analyze survival probability and success rate of the restorations. CDA rating of Empress CAD and emax CAD was compared with Log rank test ($\alpha = 0.05$).
Results: The survival rates of ceramic Empress CAD and emax CAD laminate veneers were 97.8 % and 100 % respectively ($p = 0.13$). The success rate of these veneers was 92.4 % for Empress CAD and 100 % for emax CAD ($p < 0.05$). Two Empress CAD laminate veneer failed because of fracture. Other restorations had very good or good CDA scores after 5 years. The periodontal parameters were not significantly different between first and fifth years except plaque index. The mean score of patients' satisfaction was 95.5 ± 8.4.
Conclusions: Chair-side computer-aided design/computer-aided manufacturing ceramic laminate veneers were clinically successful restorations with mean survival rate of 99.0 % and success rate of 96.4 % after 5 years.

1. Introduction

The computer-aided design/computer-aided manufacturing (CAD/CAM) systems have been advanced dramatically over the last decades. Recently, technological developments in CAD/CAM systems have enabled clinicians and dental laboratories to manufacture various kind of restorations using different materials. Preservation of tooth structure using conservative treatments results in the longevity of restored teeth over time [1]. In comparison to full coverage crowns, ceramic laminate veneers are minimal invasive treatment method in restorative dentistry and can be used to correct tooth form, position and color. Additionally, bonded restorations including ceramic laminate veneers are associated with less secondary caries and gingival inflammation compare to traditional metal ceramics [2]. Introducing of new materials for CAD/CAM systems and improvement in bonding techniques has made more conservative treatments such as laminate veneers possible in one visit CAD/CAM dentistry [3,4].

Ceramic veneers are highly esthetic restorations with predictable long term results when placed by experienced operator and with appropriate patient selection. Differences in survival rate in clinical studies can be related to their clinical or statistical methodology.

In a systematic review by Layton and Clarke [5] estimated the 5 and 10-year cumulative survival of 92.4 % (95 % CI: 89.8 %–95 %) and 66 %–94 % (95 % CI: 55 %–99 %) for nonfeldespatic veneers respectively. The estimated cumulative survival for feldspathic porcelain veneers was 95.7 % (95 % CI: 92.9 %–98.4 %) at 5 years and 95.6 % (95 % CI: 93.8 %–97.5 %) at 10 years in another systematic review. [6]

Survival rate of 94 % (95 % CI: 87 %–100 %) for glass-ceramic, and 87 % (95 % CI: 82 %–93 %) for feldspathic porcelain veneers were

* Corresponding author at: #400-Sheikhsadoogh Shomali St., Sheikhsadoogh Cross Road, Isfahan University of Medical Sciences, Isfahan, 81648-13315 Iran.
E-mail addresses: savabi@hotmail.com, savabi@dnt.mui.ac.ir (O. Savabi).

https://doi.org/10.1016/j.jpor.2018.05.004
1883-1958/

estimated by Morimoto et al. [7] in a systematic review on clinical outcome of veneers made by different types of ceramic. They also found that major complications of veneers include debonding (2 %), fracture (4 %), secondary caries (1 %) marginal discoloration (2 %) and endodontic problems (2 %) [7].

Albanesi et al. [8] indicated that ceramic laminate veneers with or without incisal coverage have high survival rates (88 % and 91 % respectively) and both preparation designs are appropriate for the conservative treatment of anterior teeth.

On the contrary some clinical studies showed high failure rates for ceramic laminate veneers [9–11]. In a retrospective study veneers that made by students and staff of Birmingham Dental Hospital were evaluated [10]. They reported that more than 90 % of studied veneers were placed on unprepared enamel and concluded that lack of tooth preparation might be the major factors for high failure rate of 42 % [10]. Burke and Lucarotti [11] reported an estimated cumulative 10 years survival rate of 47 % for these restorations. This study examined the recorded intervals between placing a porcelain veneer and re-intervention on the same tooth according to the data obtained from General Dental Services (GDS) of England and Wales [11]. The authors was not precisely reported material used for veneers, preparation method, and bonding procedure and it is possible that preparation may not met the standard criteria and veneers may have been bonded to compromised tooth substances [11]. Walls [9] used ceramic veneers for restoring worn and fractured anterior teeth and observed 14 % failure due to fracture and/or loss of porcelain veneers after five years. Unfavorable occlusion and large exposed dentine surfaces seemed to have been a factor for this high failure rate.

Biological and technical complications of ceramic laminate veneers include loss of retention, fracture, unfavorable esthetics, periodontal complications, caries, and tooth fracture [9,12–14]. The most common reasons for failure in clinical trials evaluating porcelain veneers are fracture and debonding. Locating the veneer margins on composite restorations often resulted in marginal discoloration and recurrent caries [12]. The strong bond between a porcelain veneer and the tooth structure (especially enamel) results in low failure rate (0–5 %) due to loss of bonding and fracture [15–17]. Fracture is still the main reason for a failure of ceramic veneers. Therefore, the use of materials with different mechanical properties is of special interest.

The CAD/CAM restoration can be made in one visit and new equipment and software have been shown to result in improved marginal fit. Introduction of new sophisticated softwares and milling machines provide new possibilities in dentistry. Bluecam's camera provides greater depth of field and precision. It provides a uniform field of illumination for increased accuracy. The built-in "shake control" is a specific characteristic of Bluecam that eliminates blurry images and produces significantly more detailed images [4]. Reports on clinical outcomes and survival rate of CAD/CAM laminate veneers are limited [18].

Two types of ceramics for CAD/CAM technology are IPS Empress CAD and emax CAD (Ivoclar Vivadent, Schaan, Liechtenstein) glass ceramics blocks. These materials are industrially manufactured in a reproducible manner in high-quality materials [19,20].

The aim of this retrospective study was to compare the survival, modified CDA criteria [21], and periodontal parameters of laminate veneers made by IPS Empress CAD and emax CAD over 60 months. The null hypothesis was that there would be no significant difference in the clinical performance of laminate veneers which were made with IPS Empress CAD blocks and emax CAD blocks.

2. Materials and methods

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study. In this retrospective study, 71 patients (54 women and 17 men) with a mean age of 34.9 ± 11.0 years (range 19–62 years) who had received CEREC laminate veneers between March to November 2009 were evaluated. This study was approved by Research Ethics Committee of Isfahan University of Medical Sciences (IR.MUI.REC:3.400). The studied restorations consisted of 197 laminate veneers (Table 1). The indications for veneers were discoloration, diastema closure, and correction of incisal plane and improving the patient's smile. All the restored teeth were vital to cold testing (Odontotest; Fricar A.G. Zurich, Switzerland). The inclusion criteria were to receive laminate veneers made using CEREC AC Bluecam from the same private practice during the above-mentioned time span and all laminate veneers provided in this time interval were included in the study.

Table 1
Distribution of the studied laminate veneers.

		Central incisor	Lateral incisor	Canine	Total
Empress CAD	Maxillary	41	29	10	80
	Mandibular	4	4	4	12
	Total	45	33	14	92
emax CAD	Maxillary	37	28	14	79
	Mandibular	10	8	8	26
	Total	47	36	22	105
Total		92	69	36	197

2.1. Clinical procedures

Clinical treatment was performed by one prosthodontist in a private dental clinic. The clinician prepared, fabricated and placed all restorations in one appointment. Before preparation a diagnostic wax up was made on study cast to satisfy the aesthetic requirements' of the patient. The wax up was not indicated in cases with tooth discoloration. A silicone index was made from wax up or unprepared teeth to use for evaluation of the amount of tooth reduction. The Brasseler laminate veneer burs kit (Brasseler, Savannah, GA, USA) was used for tooth preparation. The procedure began with the use of depth cuts and finalized using a round ended diamond bur. The preparation protocol was as follows: labial reduction was 0.5–0.7 mm with a long chamfer supra-gingival margin and incisal butt joint reduction of 0.5–1.0 mm, with more than 80 % of enamel remaining. The contact with adjacent teeth was not removed unless the proximal surfaces had caries or a restoration present.

After preparation, the teeth were isolated, sprayed with Optispray (Sirona, Bensheim, Germany) and scanned with CEREC BlueCam (CEREC AC; Sirona,) from incisal and buccul view. The occlusal bite registration was made by Virtual CADbite (Ivoclare Vivadent) and then scanned as the antagonist occlusion. Restorations were designed digitally (CEREC 3D 3.85; Sirona) and milled from IPS Empress CAD or emax CAD (Ivoclar-Vivadent). No randomization was used for selection of blocks. Laminate which were made by emax CAD were checked for fit and contour and then stained and sintered in furnace (P300; Ivoclar-Vivadent) according to the instructions of the manufacturer. For both Empress and emax CAD groups, after try in and approval of fit, color, and contour, the inner surface of veneers was treated with 9.5 % hydrofluoridric acid (Bisco, Schaumburg, IL,USA: 1 min for Empress CAD and 20 s for emax CAD) and porcelain primer (Bis-silane; Bisco, for 1 min). The teeth were etched with 35 % phosphoric acid gel, rinsed, dried, and treated with dentin bonding agent (All-bond 2; Bisco) according to the manufacturer's recommendations. The veneers were adhesively luted with a light-curing luting composite

Please cite this article in press as: F. Nejatidanesh, et al., Five year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers — a retrospective study, J Prosthodont Res (2018), https://doi.org/10.1016/j.jpor.2018.05.004

Table 2
List of used adhesive and luting materials and their applications.

Trade name[a]	Instruction
UNI-ETCH (32 % H_3PO_4)	Etch enamel and dentin for 15 s. Rinse thoroughly and remove excess water with a brief burst of air.
Porcelain etchant (9.5 % hydrofluoridric acid)	Apply on the surface 1 min for Empress CAD and 20 s for emax CAD.
Bis-silane	Rinse the intaglio surface of ceramic and air dry. Mix the BIS-SILANE one drop of bottles A & B. Brush on 1–2 thin coats of BIS-SILANE to the internal surface of the etched porcelain restoration for 1 min. Dry with air syringe.
All-bond 2 (PRIMERS A & B)	Apply 5 consecutive coats of mixed primer A and B to enamel and dentin. Dry surfaces for 5–6 s with an air syringe.
All-bond 2 (D/E RESIN)	Brush a thin layer of D/E resin over enamel/dentin and intaglio surface of treated ceramic veneers. Do not light cure!
Choice 2	Apply desired shade luting agent into the intaglio surface of the veneer. Seat veneer on tooth with gentle pressure. Remove excess with clean brush. Light cure for 3 s and after removing excess cement light polymerize for 30 s per surface.

[a] Manufacturer: Bisco, Schaumburg, IL, USA.

Fig. 1. (A) Preoperative view. (B) Preparation for ceramic laminate veneers maxillary central incisors to second premolars (lateral incisor is missing). (C) Sintered emax veneers were luted.

Table 3
Evaluation criteria based on the modified California Dental Association guidelines.

	Alfa	Bravo	Charlie	Delta
Shade match	No mismatch	Slight mismatch	Gross mismatch	Color falls outside the scale
Marginal gap	No probe catch	Slight probe catch but no gap	Gap with exposure of tooth	Restoration is mobile, fractured, or missing
Fracture	No fracture	Chipping of porcelain that does not impair esthetics or function and does not expose tooth structure	–	Chipping of porcelain impairing esthetics and function or exposing tooth structure
Loss of retention	No debonding	Debonding, may be re-cemented	–	Debonding, cannot be re-cemented
Hypersensitivity	No hypersensitivity when an air syringe is activated for 2 s at distance of 2.5 cm from the restoration	Hypersensitivity disappearing after removal of the stimulus	–	Spontaneous pain or the pain does not disappear after removal of the stimulus

(Choice 2; Bisco). After removing the excess of luting agent with a brush and dental floss the restorations were light polymerized for 3 s (blue phase C8; Ivoclar Vivadent) and the excess of cement was removed. The restorations were light polymerized for additional 30 s. Table 2 is the list of used materials for luting and their application procedures. The occlusion was refined as needed, and veneers were polished with polishing disk (Sof-lex; 3M ESPE, St Paul, MN, USA) and pumice paste (Fig. 1A–C).

2.2. Data registration

Modified CDA guidelines (Table 3) were used to evaluate the quality of restorations regarding shade match, marginal gap, fracture, loss of retention, and hypersensitivity [4,21]. The survival time was defined as the period from luting the laminate veneers and ending when the restoration showed an irreparably problem. Porcelain fracture, debonding (which cannot rebond) and unacceptable esthetic quality or function were defined as the failure. The treatment was also considered a failure when the abutment tooth was extracted following a biologic complication (root fracture, endodontic and/or periodontal problems). Gingival index (GI), plaque index (PI) (Table 4), bleeding on probing (BOP), and probing pocket depth (PPD) were also recorded for the abutment teeth and antagonist sound teeth as the control. Success was defined as no complication even repairable including debounding (even if it can recemented) and ceramic fracture (even repairable). PPD was analyzed by means of 4-point periodontal probing (mesial, buccal, distal, and palatal/lingual). Location of restoration margins recorded as subgingival, supragingival, and equal to free gingival margin. The restorations were evaluated after 12 and 60 months by 2 independent prosthodontists. Agreement between the two clinicians for the CDA characteristics of restorations and soft tissue parameters were 92 %. Both examiners evaluated the restorations and if there was any disagreement between them, they were resolved through discussion. If the patients had any problem they were asked to call the clinic between the scheduled follow up sessions and the data were registered.

The patients were asked to register their overall satisfaction on a horizontal line, 100 mm in length, using a visual analogue scale (VAS: 0 for extremely dissatisfied and 100 for extremely satisfied). No patients were lost from the study and all 197 veneers placed were evaluated by statistical analysis.

2.3. Statistical analysis

The data were evaluated using descriptive statistics. Kaplan–Meier analysis and the log rank test were used to analyze and compare the survival probabilities and success rate (complication

Please cite this article in press as: F. Nejatidanesh, et al., Five year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers — a retrospective study, J Prosthodont Res (2018), https://doi.org/10.1016/j.jpor.2018.05.004

Table 4
Plaque and gingival indices criteria.

Score	Plaque index[a]	Gingival index
0	No plaque in the gingival area	Normal mucosa
1	Presence of a film of plaque	Mild inflammation Slight color change and edema
2	Moderate visible plaque Accumulations[b]	Moderate inflammation Redness, edema
3	Abundant plaque presents[b]	Severe inflammation Marked redness, edema, clceration, and spontaneous bleeding

[a] The surface is tested by running the side of a probe along the abutment surface at the entrance to gingival sulcus.
[b] Can be seen by the naked eye.

Table 5
Modified California Dental Association rating, number and percentage (in parenthesis) of the laminate veneers.

	Studied feature	After 1 year				After 5 years				Significance[a]
		Acceptable		Not acceptable		Acceptable		Not acceptable		
		Alfa	Bravo	Charlie	Delta	Alfa	Bravo	Charlie	Delta	
Empress CAD	Shade match	78 (84.8)	14 (15.2)	0	0	75 (83.3)	15 (16.7)	0	0	$\chi^2 = 0.004$; $p = 0.95$
	Marginal gap	89 (96.7)	3 (3.3)	0	0	82 (91.1)	8 (8.9)	0	0	$\chi^2 = 3.19$; $p = 0.07$
	Fracture	92 (100)	0	0	0	87 (92.7)	3 (5.5)	0	2[b] (1.8)	$\chi^2 = 5.11$; $p = 0.02$
	Loss of retention	89 (96.4)	3[d] (3.6)	0	0	86 (95.6)	4[d] (4.4)	0	0	$\chi^2 = 0.15$; $p = 0.70$
	Hypersensitivity	85 (92.4)	7[c] (7.6)	0	0	90 (100)	0	0	0	$\chi^2 = 7.24$; $p = 0.007$
emax CAD	Shade match	97 (92.4)	8 (7.6)	0	0	94 (89.5)	11 (10.5)	0	0	$\chi^2 = 0.52$; $p = 0.47$
	Marginal gap	103 (98.1)	2 (1.9)	0	0	101 (96.2)	4 (3.8)	0	0	$\chi^2 = 0.68$; $p = 0.41$
	Fracture	105 (100)	0	0	0	105 (100)	0	0	0	–
	Loss of retention	105 (100)	0	0	0	105 (100)	0	0	0	–
	Hypersensitivity	105 (100)	0	0	0	105 (100)	0	0	0	–

[a] Log rank test.
[b] Fractured veneers on tooth 23 (after 24 months) and on tooth 11 (after 20 months) were replaced by e-max laminate veneers.
[c] The hypersensitivity was reported after cementation which improved with one month.
[d] Debonded veneers were all recemented.

free cases) of different ceramic blocks. The CDA score comparison between two studied ceramics and the first and fifth years was performed using log rank test.

Some patients received more than one laminate veneer. In a patient with more than one restoration, the clinical outcome of all veneers may be affected by individual characteristics (favorably or unfavorably) resulting a clustering outcomes. For this reason clustered units were separated prior to analysis [22]. A nonclustered data sample of 71 from the 197 (entire restorations) was evaluated for survival analysis. A random number table was used to randomly identify a single restoration in patients who had more than one restoration. In patients who received only one unit, each restoration was included for analysis. Survival of randomly selected samples was analyzed and compared with the survival of entire sample [22]. Cox regression performed for analyzing the influence of ceramic material type on survival and success rate of studied laminate veneers.

Wilcoxon signed ranked test for paired samples was used for comparing the soft tissue parameters after the first and fifth years and also the veneered and control teeth. McNemar's nonparametric test was used for comparing BOP of the studied and control teeth ($\alpha = 0.05$ for all comparisons). The statistical analysis was performed by using statistical software (IBM SPSS ver. 22, IBM Corp., Armonk, NY, USA).

3. Results

A total of 197 laminate veneers in 71 patients were evaluated (2.77 laminate per patients). All the teeth were vital. Table 1 shows the distribution of restored teeth and Table 5 presents the CDA rating of the studied veneers after first and fifth years. Two Empress CAD laminate veneers failed after 20 and 24 months because of fracture. Other restorations had very good or good CDA scores after 5 years. One patient experienced debonding of three of his veneers during present study, which were all recemented. All debondings were adhesive from surfaces of the teeth (Table 5; loss of retention).

Five year Kaplan–Meier survival rate of the studied veneers for Empress CAD and emax CAD were 97.8 % (95 % CI: 95.8–99.8 %) and 100 % respectively ($\chi^2 = 2.30$; $p = 0.13$) (Fig. 2). Regarding to

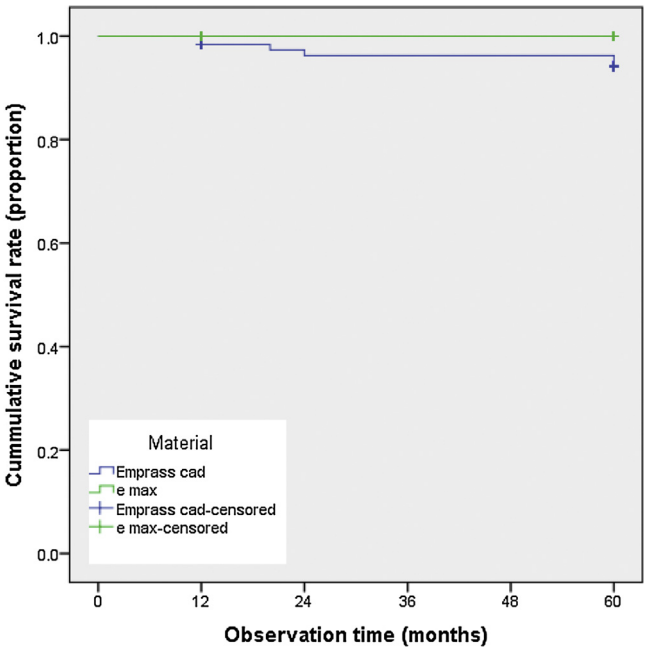

Fig. 2. Kaplan–Meier survival rate of 5 years for chair-side CAD/CAM ceramic laminate veneers.

Please cite this article in press as: F. Nejatidanesh, et al., Five year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers — a retrospective study, J Prosthodont Res (2018), https://doi.org/10.1016/j.jpor.2018.05.004

Table 6
Gingival index (GI), plaque index (PI), and bleeding on probing (BOP) scores of studied laminate veneers (percentage in parenthesis).

		PI				GI			BOP	
		0	1	2	3	0	1	2	Negative	Positive
Empress CAD	After 1 year	60 (65.2)	25 (27.2)	7 (7.6)	0	87 (94.6)	5 (5.4)	0	83 (90.2)	9 (9.8)
	After 5 years	55 (61.2)	23 (25.6)	8 (8.8)	4 (4.4)	82 (91.1)	7 (7.8)	1 (1.1)	80 (88.9)	10 (11.1)
Significance		$p < 0.001$[a]				$p = 0.08$[a]			$p = 0.63$[b]	
emax CAD	After 1 year	72 (68.6)	33 (31.4)	0	0	96 (91.4)	9 (8.6)	0	93 (88.6)	12 (11.4)
	After 5 years	65 (61.9)	30 (28.6)	7 (6.7)	3 (2.8)	93 (88.6)	12 (11.4)	0	90 (85.7)	15 (14.3)
Significance		$p < 0.05$[a]				$p = 0.07$[a]			$p = 0.25$[b]	

[a] Wilcoxon sign rank test for paired sample.
[b] McNemar's nonparametric test.

success rate when debonded veneers accounted for complication the success rate of Empress CAD decreased to 92.4 % (95 % CI: 88.5–96.3). This success rate was significantly less than emax CAD ($p = 0.04$). The estimated cumulative survival rates of the entire sample (99.0 %; 95 % CI: 98.3–99.7) and random nonclustered sample (98.0 %; 95 % CI: 96.9–99.1) were not significantly different ($\chi^2 = 0.34$; $p = 0.56$). Cox regression showed no influence of the ceramic type on survival (HR = 1.00; 95 % CI: 0.75–1.33) and success (HR = 0.92; 95 % CI: 0.69–1.23) rates of studied laminate veneers.

Tables 6 and 7 show the soft tissue conditions of restored teeth. Wilcoxon signed-rank test for paired samples showed that there was no significant differences in gingival index, pocket depth, and plaque index of restored and control teeth ($p = 0.10$, $p = 0.13$, and $p = 0.40$ respectively). BOP of the studied and control teeth was not significantly different ($p = 0.9$). One hundred and nineteen (60.4 %) of margins located at the level of free gingiva and 42 (21.3 %) and 36 (18.3 %) were subgingival and supragingival respectively. The mean score for patients' VAS was 95.5 ± 8.4.

Table 7
Probing Pocket Depth (PPD) of studied veneers after 1 and 5 years (percentage in parenthesis).

	PPD mm	After 1 year	After 5 years
Empress CAD	1	44 (47.8)	40 (44.5)
	2	46 (50.0)	48 (53.3)
	3	2 (2.2)	2 (2.2)
	Significance[a]	$p = 0.08$	
Emax CAD	1	49 (46.7)	45 (42.9)
	2	53 (50.5)	57 (54.3)
	3	3 (2.9)	3 (2.9)
	Significance[a]	$p = 0.08$	

[a] Wilcoxon sign rank test for paired sample.

4. Discussion

In the present study, 197 chair-side CAD/CAM ceramic laminate veneers were assessed in a 5 year follow up. The hypothesis that there would be no significant difference in the clinical performance of the laminate veneers which were made with IPS Empress CAD blocks and emax CAD blocks was rejected for some of the CDA rating criteria (fracture, hyper sensitivity, and loss of retention). But the present study could not prove significant difference in failure between 5-year survival rate of laminates made by two different blocks (Log Rank test: $\chi^2 = 2.30$; $p = 0.13$, Cox regression: HR = 1.00; 95 % CI: 0.75–1.33). However regarding the success rate (when the debonding of the veneers were accounted) Empress CAD was significantly lower than emax CAD ($p = 0.04$). The 5 year survival rate (Kaplan–Meier) of studied restorations was 99.0 % (95 % CI: 98.2–99.7 %) with no difference between entire cluster samples and noncluster samples ($\chi^2 = 0.34$; $p = 0.56$). A prosthetic restorative system can be considered successful if it demonstrates a survival rate of 95 % after 5 years and 85 % after 10 years [23]. The survival rates of the recent systematic reviews showed that the 5–10 year survival rate of laminate ceramic veneers made from feldespatic and non feldespatic ceramics ranged from 88 % to 95.7 % which is comparable with present 99.0 % [5–8].

The clinical reports on veneers fabricated with CEREC system are scarce, and have been performed on restorations made by early generations of chair-side CAD/CAM systems [18]. Wiedhahn et al. [18] reported 96.9 % survival rate for CAD/CAM laminate veneers after 5 years. This result is similar to the current study. CAD/CAM technology through innovations in digital optical impressions, virtual design softwares and precise milling machines have introduced new era in dentistry.

The evaluation of the quality of veneers using CDA criteria showed that all the restorations were acceptable except two fractured failed Empress CAD veneers. Comparison of these criteria revealed that after 5 years the Empress CAD veneers significantly had more fracture than the first year ($\chi^2 = 5.11$; $p = 0.02$) (Table 5). The emax CAD veneers had no fracture (compared to Empress CAD: $\chi^2 = 5.83$; $p = 0.02$) which can be the result of its higher flexural strength (360 MPa). Low flexural strength of ceramic, inadequate porcelain thickness and subsurface flaws produced in machining are among the reason for fracture of CAD/CAM ceramic restorations [4]. Morimoto et al. [7] showed that fracture and chipping occurred in 4 % of ceramic laminate veneers in a recent meta-analysis. Fracture of the ceramic after the first year may be more related to fatigue or crack propagation within the ceramic, resulting from masticatory forces [16,24,25]. In a study by Gurel et al. [25] the rate of porcelain fracture and chipping was 3.4 % which many of them could be repaired clinically. To prevent crack propagation, sufficient and even thickness of ceramic, minimal thickness of luting composite, and appropriate polishing after ceramic adjustment should be provided [22]. In addition, extending the preparation to dentine with lower modulus of elasticity than ceramic can provide a flexible base for restoration which results in higher fracture rate than laminate veneers supported by enamel [25,26].

In fifth year there was more Bravo score regarding marginal fit but no significant difference was found between first and fifth years ($\chi^2 = 3.19$; $p = 0.07$ and $\chi^2 = 0.68$; $Pp = 0.41$ for Empress CAD and emax CAD respectively). There was also no significant difference between marginal adaptation scores of two studied ceramic ($\chi^2 = 2.97$; $p = 0.09$). The results of current study were similar to those reported good or very good marginal fit in all porcelain veneers in a previous study by Gurel et al. [25]. Several *in vivo* studies have reported acceptable marginal adaptation for 65–98 % of ceramic laminate veneers which resulted in a good periodontal response [27–29]. Aboushelib et al. [30] reported better marginal fit of laminate veneers made by pressed ceramic

Please cite this article in press as: F. Nejatidanesh, et al., Five year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers — a retrospective study, J Prosthodont Res (2018), https://doi.org/10.1016/j.jpor.2018.05.004

than CAD/CAM veneers. But a recent study on CAD/CAM ceramic implant supported crowns showed better marginal fit for these restorations [31].

The early hypersensitivity of some teeth in Empress CAD group after cementation was not reported after 5 years. No hypersensitivity was seen in emax CAD groups (Compare to Empress CAD: $\chi^2 = 8.24$; $p = 0.04$) (Table 5). This post-operative sensitivity can be due to the removal of tooth structure especially when the dentin exposed during preparation. Hypersensitivity also can be the result of Microleakage at the composite/tooth interface. Microleakage is minimal when the preparation margins were located completely in enamel [12].

The high percentage of Bravo scores in color match was the result of darker adjacent teeth which were different to the veneers. Fasbinder [32] showed that this color mismatch increased over time and could be as a result of a tooth color change instead of restorations themselves. The Empress CAD and emax CAD were similar regarding shade match ($\chi^2 = 1.58$; $p = 0.21$).

One patient experienced debonding of three of his veneers during present study, which were all adhesive type from the surface of teeth and recemented again. This could be because of thinner layer of enamel and more sclerotic dentine of this older patient (58 year old) [25]. The success of the porcelain veneers greatly depends on the strength and durability of bond between tooth surface, luting agent and ceramic veneer. Bond failures may also influence the marginal staining and gaps, and fractures of the ceramic. Despite the advances in dentine bonding agents, bonding to enamel is more stable than dentine [16,17]. Bonding to enamel consist of mechanical interlocking and is more stable than bond to dentine. Dentin is nonhomogenous, has moisture, and may have sclerotic areas [16,17]. On the other hand dentin has much lower modulus of elasticity than porcelain. This less rigid base for ceramic veneer resulted in flexion of tooth and higher fracture and debonding rates than enamel-supported restorations [25,33]. Tooth preparation should preferably preserve the tooth structure and confined to the enamel. This will guarantee greater strength of tooth and high bond strength. Discoloration may demand more preparation. Teeth with abrasion or erosion (for example in older patients) have thin enamel layer. These conditions make the preservation of enamel more critical and difficult. No veneers made by emax CAD were debonded (compare to Empress CAD: $\chi^2 = 8.08$; $P = 0.004$).

Regards to soft tissue status, the results of present study showed that the plaque index was increased in fifth year, but pocket probing depth, BOP, and gingival index were not significantly changed (Table 6). Polishing of the margins can remove the porcelain glaze at the cervical border of the restoration and lead to increased surface roughness. This along with small cervical marginal defects can cause an increase in plaque retention at the margin site [12,34]. Level of patient's compliance to oral hygiene play a significant role for removing plaque and must be mentioned in follow up sessions.

Location of the margins and contour of ceramic laminate veneers can affect the soft tissue status. Locating the margins at or above the free gingiva can facilitate the maintenance of hygiene [25,26]. In the current study most of the laminate veneer margins were located at or above the free gingiva margin (78.7 %).

The patient satisfaction with chair side ceramic laminate veneers was generally high (mean 95.5 ± 8.4). One of the reasons for this satisfaction was that the treatment was completed at a single visit.

One of the limitations of present study was that the results of this study were obtained from one private practice and cannot be general. The experience of clinician can play a significant role in clinical success. As same as all retrospective study this study has certain limitation including poor control over the confounding factors and covariates, and lack of randomization. Furthermore due to uneven distribution of the restorations for different tooth types and between mandible and maxilla, a statistical analysis of these potential influencing factors were not possible. Another limitation of the current study is that the CAD/CAM blocks was selected according to the availability and this nonrandomized selection can influence the results.

5. Conclusion

Within the limitations of this study it can be concluded that:

1. Chair-side CEREC AC ceramic laminate veneers were clinically successful restorations with mean survival rates of 99.0 % (95 % CI: 98.2–99.7) after 5 years.
2. The CDA criteria were similar between first and fifth years, with exception of fracture status in Empress CAD group which was less favorable.
3. The success rate of emax CAD veneers was significantly higher than Empress CAD veneers.
4. The laminates made with emax CAD showed no fracture, hypersensitivity and loss of retention during 5 year follow up.

Acknowledgements

This study was approved by Research Ethics Committee of Isfahan University of Medical Sciences (IR.MUI.REC: 3.400). This research was a part of Research Grant# 393400 supported by Isfahan University of Medical Sciences.

Based on a thesis submitted to the post graduate school of Isfahan University of Medical Sciences in partial fulfillment of the requirement for the Master of Science Degree.

References

[1] Torbjörner A, Fransson B. Biomechanical aspects of prosthetic treatment of structurally compromised teeth. Int J Prosthodont 2004;17:135–41.
[2] Pippin DJ, Mixson JM, Soldan-Els AP. Clinical evaluation of restored maxillary incisors: veneers vs. PFM crowns. J Am Dent Assoc 1995;126:1523–9.
[3] Magne P. Immediate dentin sealing: a fundamental procedure for indirect bonded restorations. J Esthet Restor Dent 2005;17:144–54.
[4] Nejatidanesh F, Amjadi M, Akouchekian M, Savabi O. Clinical performance of CEREC AC Bluecam conservative ceramic restorations after five years—a retrospective study. J Dent 2015;43:1076–82.
[5] Layton DM, Clarke M. A systematic review and meta-analysis of the survival of non-feldspathic porcelain veneers over 5 and 10 years. Int J Prosthodont 2013;26:111–24.
[6] Layton DM, Clarke M, Walton TR. A systematic review and meta-analysis of the survival of feldspathic porcelain veneers over 5 and 10 years. Int J Prosthodont 2012;25:590–603.
[7] Morimoto S, Albanesi RB, Sesma N, Agra CM, Braga MM. Main clinical outcomes of feldspathic porcelain and glass-ceramic laminate veneers: a systematic review and meta-analysis of survival and complication rates. Int J Prosthodont 2016;29:38–49.
[8] Albanesi RB, Pigozzo MN, Sesma N, Laganá DC, Morimoto S. Incisal coverage or not in ceramic laminate veneers: a systematic review and meta-analysis. J Dent 2016;52:1–7.
[9] Walls AW. The use of adhesively retained all-porcelain veneers during the management of fractured and worn anterior teeth: part 2. Clinical results after 5 years of follow-up. Br Dent J 1995;178:337–40.
[10] Shaini FJ, Shortall AC, Marquis PM. Clinical performance of porcelain laminate veneers. A retrospective evaluation over a period of 6.5 years. J Oral Rehabil 1997;24:553–9.
[11] Burke FJ, Lucarotti PS. Ten-year outcome of porcelain laminate veneers placed within the general dental services in England and Wales. J Dent 2009;37:31–8.
[12] Peumans M, Van Meerbeek B, Lambrechts P, Vanherle G. Porcelain veneers: a review of the literature. J Dent 2000;28:163–77.
[13] Layton D, Walton T. An up to 16-year prospective study of 304 porcelain veneers. Int J Prosthodont 2007;20:389–96.
[14] Friedman MJ. Commentary. Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: a literature review. J Esthet Restor Dent 2012;24:266–7.
[15] Magne P, Kwon KR, Belser UC, Hodges JS, Douglas WH. Crack propensity of porcelain laminate veneers: a simulated operatory evaluation. J Prosthet Dent 1999;81:327–34.

Please cite this article in press as: F. Nejatidanesh, et al., Five year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers — a retrospective study, J Prosthodont Res (2018), https://doi.org/10.1016/j.jpor.2018.05.004

[16] Piemjai M, Arksornnukit M. Compressive fracture resistance of porcelain laminates bonded to enamel or dentin with four adhesive systems. J Prosthodont 2007;16:457–64.
[17] Aykor A, Ozel E. Five-year clinical evaluation of 300 teeth restored with porcelain laminate veneers using total-etch and a modified self-etch adhesive system. Oper Dent 2009;34:516–23.
[18] Wiedhahn K, Kerschbaum T, Fasbinder DF. Clinical long-term results with 617 Cerec veneers: a nine-year report. Int J Comput Dent 2005;8:233–46.
[19] Giordano R. Materials for chairside CAD/CAM-produced restorations. J Am Dent Assoc 2006;137 Suppl:14s–21s.
[20] Vichi A, Sedda M, Del Siena F, Louca C, Ferrari M. Flexural resistance of Cerec CAD/CAM system ceramic blocks. Part 1: chairside materials. Am J Dent 2013;26:255–9.
[21] California Dental Association. Quality evaluation for dental care. Guidelines for assessment of clinical quality and professional performance. Los Angeles: California Dental Association; 1977.
[22] Layton DM, Walton TR. The up to 21-year clinical outcome and survival of feldspathic porcelain veneers: accounting for clustering. Int J Prosthodont 2012;25:604–12.
[23] Pröbster L. Klinische Erfahrung mit vollkeramischem Zahnersatz — Ein Rückblick. In: Kappert HF, editor. Vollkeramik: Werkstoffkunde — Zahntechnik — Klinische Erfahrung. Berlin: Quintessence Verlag; 1996.
[24] Addison O, Fleming GJ, Marquis PM. The effect of thermocycling on the strength of porcelain laminate veneer (PLV) materials. Dent Mater 2003;19:291–7.
[25] Gurel G, Morimoto S, Calamita MA, Coachman C, Sesma N. Clinical performance of porcelain laminate veneers: outcomes of the aesthetic pre-evaluative temporary (APT) technique. Int J Periodontics Restorative Dent 2012;32:625–35.
[26] Calamia JR, Calamia CS. Porcelain laminate veneers: reasons for 25 years of success. Dent Clin North Am 2007;51:399–417.
[27] Christensen GJ, Christensen RP. Clinical observations of porcelain veneers: a three-year report. J Esthet Dent 1991;3:174–9.
[28] Strassler HE, Weiner S. Seven to ten year clinical-evaluation of etched porcelain veneers. J Dent Res 1995;74:176.
[29] Dumfahrt H, Schäffer H. Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: part II—clinical results. Int J Prosthodont 2000;13:9–18.
[30] Aboushelib MN, Elmahy WA, Ghazy MH. Internal adaptation, marginal accuracy and microleakage of a pressable versus a machinable ceramic laminate veneers. J Dent 2012;40:670–7.
[31] Nejatidanesh F, Shakibamehr AH, Savabi O. Comparison of marginal and internal adaptation of CAD/CAM and conventional cement retained implant-supported single crowns. Implant Dent 2016;25:103–8.
[32] Fasbinder DJ. Clinical performance of chairside CAD/CAM restorations. J Am Dent Assoc 2006;137 Suppl:22s–31s.
[33] Burke FJ. Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: a literature review. J Esthet Restor Dent 2012;24:257–65.
[34] Peumans M, Van Meerbeek B, Lambrechts P, Vuylsteke-Wauters M, Vanherle G. Five-year clinical performance of porcelain veneers. Quintessence Int 1998;29:211–21.

Please cite this article in press as: F. Nejatidanesh, et al., Five year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers — a retrospective study, J Prosthodont Res (2018), https://doi.org/10.1016/j.jpor.2018.05.004